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THE PERFORMANCE OF A SMALL 14 TON TRACKED AMPHIBIAN IN CALM AND—ETC(U)

JAN 82 G FRIDSMAN, W E KLOSINSKI

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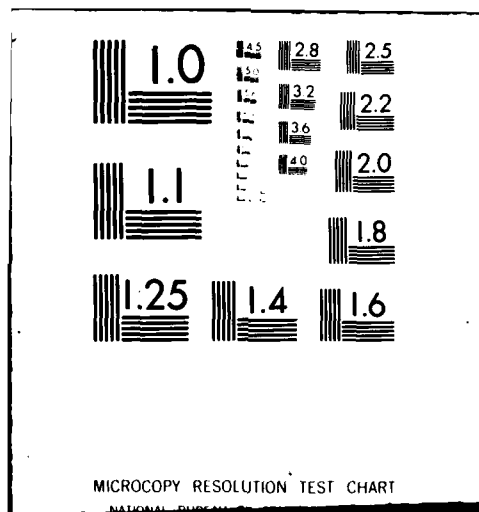
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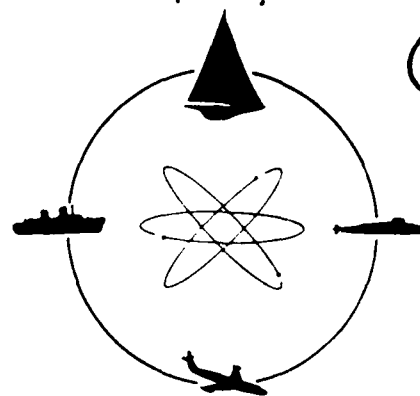
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DAVIDSON LABORATORY

Technical Report SIT-DL-82-9-2250
January 1982

THE PERFORMANCE OF A SMALL
14 TON TRACKED AMPHIBIAN IN
CALM AND ROUGH WATER

by

G. FRIDSMA AND W.E. KLOSINSKI

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by
G. Fridsma and W.E. Klosinski

Prepared for
David W. Taylor
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INTRODUCTION

Hydrodynamic performance tests on a 1/6 scale model of a small tracked amphibian were carried out as part of a general program being conducted in support of the Marine Corps Surface Mobility Exploration Development Plan. Under the direction of the David W. Taylor Naval Ship Research and Development Center (NSRDC), Code 112, which manages the Mobility Program, the Davidson Laboratory has been carrying out a series of investigations into the hydrodynamic characteristics of amphibious vehicles. This investigation is concerned with tank tests of a 14 ton tracked amphibian model, denoted as "FLASH", in calm water and head seas.

Amphibious craft of the 14 ton size must operate in essentially the same sea environment as larger 26 ton vehicles. With its inherently lower freeboard, the small craft may develop serious hydrodynamic problems such as bow immersion, which could significantly affect its behavior in calm water and waves. It is essential therefore that model tests be undertaken to identify potential problem areas, to seek solutions, and to define the hydrodynamic characteristics of these small amphibians. Changes in the hull geometry, such as track suspension position and bow planes, were explored over a range of speed to determine powering requirements and any tendency for bow immersion in both calm water and waves. Motions, accelerations, and deck wetness in the seaway were also obtained.

The tests outlined above were carried out in the Davidson Laboratory Tank No. 3 facility during the period 7 to 14 December 1981, and were witnessed in part by Mr. Walter Zeitfuss, Jr., Code 112. Along with a description of the model, test apparatus, and experimental procedures, this report also tabulates all the data, analyzes and discusses the results and makes recommendations on how to improve its hydrodynamic performance.

MODEL

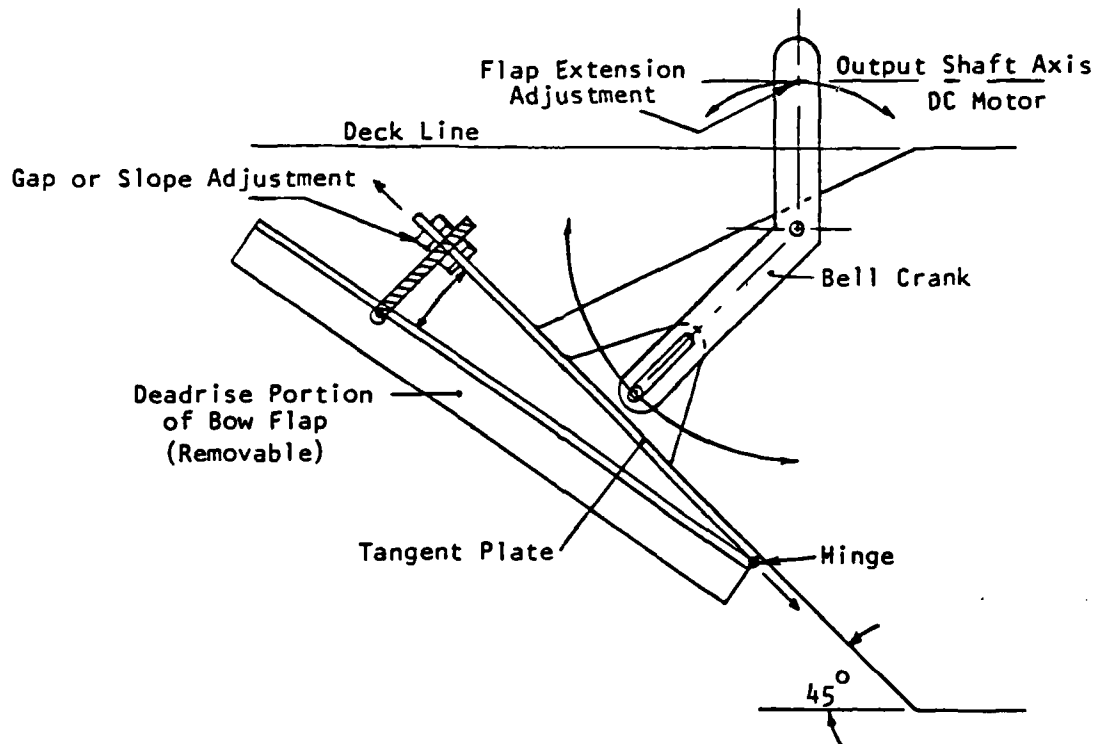
A 1/6 scale model of the FLASH amphibian was fabricated at the Davidson Laboratory according to drawings supplied by Code 112, NSRDC.

Figures 1 and 2 give a general picture of the model. In full scale values, the small amphibian has a design weight of 28,000 lb, an overall length (not including the bow flap) of 16.75 ft, an overall width of 8.83 ft, and a depth from the ground plane to the deck of 6.17 ft. It includes the water jet cavity, a retractable wheel-track suspension system, and a variable geometry bow flap.

The hull was constructed of 3/4 inch marine plywood covered with a layer of epoxy impregnated fiberglass. Catalyzed urethane hull and deck enamel was used to further seal the hull. The track wheels were made by cutting sections of plastic PVC pipe and cementing thin plastic blanks inside one end. The five ground wheels on each side were mounted on a 1/4 inch thick aluminum, horizontal bar. Retracting the wheels was a matter of remounting this bar higher up in the hull, so that the tracks were level with the hull bottom. Each track was made from a standard ribbed timing belt, which was cut to size and rejoined with small springs, which tensioned the belt. The track springs kept the tracks tight without any sag in both the extended and retracted positions. Wheel covers were made of styrofoam cylinders, which fit flush inside each wheel. These were made for tests with the wheels covered and served the purpose of streamlining the wheels as well as providing extra buoyancy.

The basic bow flap was made in two pieces; a flat plate piece, which was mounted parallel to the bottom portion of the bow, and a removable deadrise section, which was hinged to the first plate. This arrangement allowed for variations in the height and slope of the bow flap, with or without deadrise. The sketch on Page 3 describes the features of the bow flap.

The flat portion of the bow flap consisted of an aluminum plate equipped with two inside rails, which rode in channels imbedded in the



bow. Moving parallel to the 45 degree sloping bottom portion of the bow, the plate had a maximum travel of 2.30 ft full size, starting with the plate's leading edge being flush with the top sloping portion of the bow. The actual extension of this plate was accomplished through a powered remote control, which provided for fine adjustments of the flap before and during the test run.

The deadrise portion of the flap consisted of another flat plate hinged to the bottom of the first so called "tangent" plate. A 6 degree deadrise section was sandwiched to the hinged plate and extended 1 ft above the leading edge of the tangent plate. An adjustment was provided at the upper end of the hinged plate to control the gap between the two plates. With the exception of Run 79, all flap positions (with or without deadrise and with or without gap) were set with the leading edge

level with the hull deck, so that the flap would not obstruct the driver's forward vision. The adjustments for the bow flap extension and angle were included for test purposes only and are not a feature of the proposed prototype vehicle.

The model was fitted with a watertight lucite deck and is shown under test on Figure 3.

APPARATUS AND INSTRUMENTATION

Model Instrumentation

An inclinometer was mounted in the model for measuring the trim in calm water. It was further used to calibrate and reference the zero on the pitch transducer for wave tests. Also included in the model were two accelerometers, one located at the driver's station and the other at the pitch axis.

Facility Instrumentation

The Davidson Laboratory Tank No. 3 was used for conducting tests on the 1/6 scale "FLASH" model. A standard free-to-heave apparatus was coupled to the model through a drag balance and pitch pivot box. While the model was free-to-pitch and heave, it was restrained in yaw, roll, sway, and surge. The pitch axis was located 2.20 ft above the hull bottom and 8.69 ft aft of the bow, full size. The vertical displacement of the pitch axis and the angular rotation of the model about the pitch axis were measured and recorded. A wave strut ahead and to port of the model was used to monitor wave encounters and wave profile during the irregular wave runs.

The transducer signals were relayed by overhead cables to the data station on shore where they were filtered (40 Hz low pass) and processed by an on-line PDP-8e computer, which includes an analog-to-digital converter. Rough water time histories were recorded on analog magnetic tape. All tests were monitored on a direct writing oscillograph.

Wavemaker

The Tank No. 3 plunger type wavemaker, located at the far end of the tank, was used to generate irregular waves simulating a Sea State 2 (significant height = 2.2 ft). The waves consist of a quasi-random reproducible set of 100 waves having a variance density distribution approximating the Pierson-Moskowitz spectra. The experimental spectrum was measured prior to testing and is shown on Figure 4.

Photography

A color video camera was mounted on a camera carriage ahead of and to port of the model. Video recordings were made of all data runs and were monitored on a shore based TV receiver. Above water color photographs were taken of selected runs.

DATA REDUCTION

Calibrations of the instrumentation were made by applying known loads to the force balance, gravity multiples to the accelerometers, and known displacements to the motion and wave elevation transducers. During calibration, the outputs from the transducers were sent to the PDP-8e computer. All calibrations were linear, and straight lines were fitted to these data by the least squares technique.

Data channels were scanned by the PDP-8e computer at the rate of 250 Hz and stored in the computer for processing. Test results were determined from the differences between transducer outputs in the running and known static reference conditions. Velocities were computed from the time taken to travel through the data zone, which was 50 ft for calm water tests, and 150 ft for wave tests.

Processing of the calm water data resulted in the mean values for the drag, draft, and trim. For the wave tests, a peak-trough analysis was carried out on the pitch and heave motions, and the pitch axis and driver accelerations. The peak-trough analysis computes or lists for

each signal the mean and rms, the number of oscillations and buffer size, the average of the peaks and troughs, the average of the 1/3 highest and the 1/10 highest peaks and troughs, and the extreme values of the peaks and troughs. Buffers were used to suppress small oscillations associated with noise rather than the substantive time histories.

TEST PROGRAM

The object of the test program for evaluating "FLASH" was three-fold. First of all, the bow flap had to be optimized in terms of effectiveness coupled with least drag and best spray behavior. Secondly, the hydrodynamic characteristics as a function of load and track configuration had to be determined. Finally the motions and loads in irregular waves (Sea State 2) together with the added resistance were to be obtained.

The model was ballasted to two loading conditions. These full size quantities were:

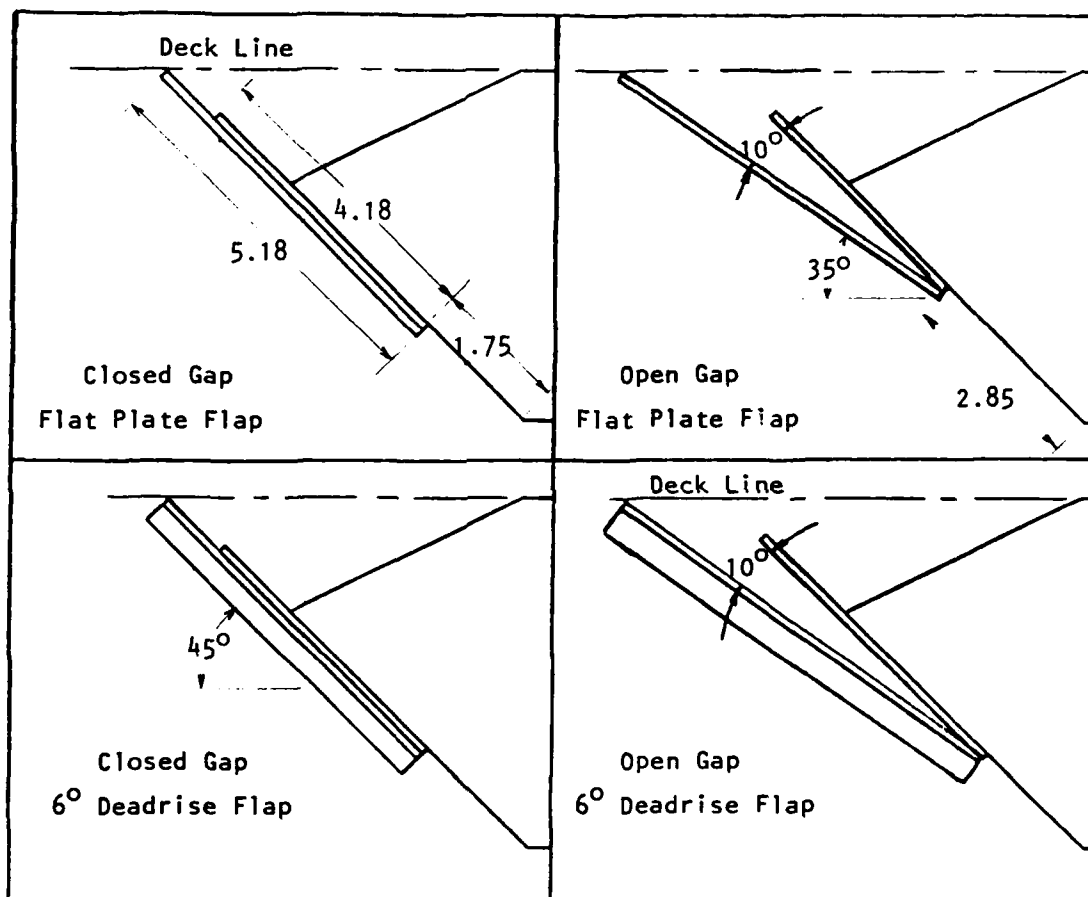
Load, lb	VCG, in. Above Ground Plane	LCG, in. Aft of Bow
25,600	42.4	104.3
28,000	42.4	107.9

Extension of the bow flap altered the CG position slightly but not more than one percent from the above values.

The parameters tested were selected from the following matrix:

Speeds	0 to 12 mph
Tracks and suspension	extended or retracted
Wheel covers	on or off
Bow flap (even with deck line, see sketch Page 7)	a) flat or 6 degree deadrise b) 45 degree or 35 degree slope (closed gap or open gap)

The extended position of the tracks corresponds to the ground plane; retracted position is with the tracks flush with the hull bottom. When the deadrise portion of the bow flap was removed, it was replaced by an equivalent weight.



BOW FLAP CONFIGURATIONS (Dimensions in Full Scale Feet)
 Open Gap is With Flap 35 Degrees Relative to Baseline

As a result of the calm water testing, optimum bow flap and track configurations were identified, namely incorporating deadrise and a 35 degree slope on the flap and running with the tracks retracted and with wheel covers on. This produced the least drag and deck wetness.

The rough water test program consisted of model tests with the optimum bow flap configuration and the wheel covers on. The two loading conditions with the tracks extended and retracted were run over the same range of speeds to obtain their effect in waves. As a result of a bow submergence problem, some special runs were made. These will be discussed later.

RESULTS

The results of the test are presented in Tables 1 through 7; numbers 1 and 2 being the calm water data and 3 through 7 the rough water data. A description follows.

TABLE	CALM/ROUGH WATER	LOAD lb	TRACK POSITION	WHEEL COVERS	BOW FLAP
1.1	Calm	25,600	Extended	off	As Noted
1.2	Calm	25,600	Retracted	off/on	As Noted
2.1	Calm	28,000	Extended	off	As Noted
2.2	Calm	28,000	Retracted	off/on	As Noted
3	Sea State 2	25,600	Extended	on	With Deadrise and Gap
4	Sea State 2	25,600	Retracted	on	With Deadrise and Gap
5	Sea State 2	25,600	Retracted	on	Maximum Up With Deadrise and Gap
6	Sea State 2	28,000	Extended	on	With Deadrise and Gap
7	Sea State 2	28,000	Retracted	on	With Deadrise and Gap

In calm water, the results are tabulated by load in short tons (s-tons) which is the full scale displacement, speed (mph), the draft (ft) or submergence of the hull bottom at the pitch axis, trim (deg) or angle of the baseline relative to the horizontal, positive bow up, drag (lb) and drag/load, drag non-dimensionalized by load in lb per short ton.

In rough water (Tables 3 through 7) each page presents data for one run and includes the peak-trough statistics associated with each data channel. The page numbers for each table (denoted by the decimal .1, .2, .3 etc.) are arranged in order of increasing speed. Statistics are included for the pitch and heave motions, where heave is defined as the height of the pitch axis above the calm water surface, and the two accelerations for the driver position and pitch axis position. The latter acceleration is denoted in the table as the CG acceleration. The statistics for each data channel are the mean and rms values, and the average, average of the 1/3 highest (significant), average of the 1/10 highest, and extreme for both the peaks and troughs. The mean value for speed and drag in lb per short ton are also included.

A video tape recording of all runs has been forwarded to Code 112, NSRDC. A scenario of this tape is included in Table 8.

DISCUSSION

Testing of the small 14 ton tracked amphibian gave a clear impression that the craft performed well in calm water. There was always a positive increase of trim with speed, indicating that the vehicle with bow flap was developing lift forward, despite the low freeboard and the negative floating trims of some of the 12.8 ton conditions with its forward LCG position. At 6 mph the bow wave comes up to the leading edge of the flap; at 8 to 10 mph a small amount of water comes over the bow flap, but the area in back of the flap is still generally clear of water; at 12 mph, the trim is sufficiently high that the leading edge of the flap is well above the bow wave. In all of these conditions (Runs 1 through 66) driver visibility as regards deck wetness was excellent, and no bow immersion problem was evident.

The calm water drag characteristics of "FLASH" are shown on Figures 5, 6 and 7 where the non-dimensionalized drag is plotted against speed for various loads and bow flap configurations. On each of the graphs, it is clear that the bow flap configurations and load

have little effect on the drag, despite the rather large changes in trim (see corresponding trim Figures 8, 9 and 10). Track retraction results in a 14 percent reduction in drag at 8 mph. An additional 5 percent reduction in drag is realized by fitting wheel covers.

The data for the LVTP-7, with the bow flap and tracks down, is used to put the performance of the 14 ton small amphibian in perspective. The LVTP-7 characteristics are indicated by solid lines on Figures 5 to 15. The LVTP-7 is a large 26 ton amphibian, 10 ft longer and 2 ft wider than FLASH. The LVTP-7 has less drag than the 14 ton vehicle on a non-dimensional basis, by about 25 percent at 8 mph (Figure 5) which shows the advantage of size. However, by retracting the tracks and adding wheel covers, the performance of FLASH can be made to approach that of the LVTP-7 (Figure 7).

The trim of the LVTP-7 is noticeably below that of FLASH, which contributes to the LVTP-7's bow burying problem (see Figures 8, 9 and 10).

The added resistance due to waves is indicated on Figures 11 and 12 for the tracks extended and tracks retracted position respectively. At 8 mph, an increase of 80 lb/ton is attributable to waves in Sea State 2, an increase of 30 percent (see Figure 12) over the calm water value. The LVTP-7 with bow flap in Sea State 2 is also shown in Figure 12; the drag/ton is very similar to the "FLASH" performance in calm water.

The heave and pitch motions (Figures 13 and 14) are not seriously changed with track position. The light load does account for a small decrease in motions. Beyond 8 mph the motions decrease with speed. At 8 mph and lower speeds, significant double amplitude motions of 2 ft of heave and 16 degrees of trim can be expected. The LVTP-7 motions, also shown, indicate similar heave behavior, but a 5 degree reduction in the significant pitch motions.

The single amplitude accelerations are presented on Figure 15. As expected the driver accelerations are slightly higher than those

at the pitch axis. Maximum significant accelerations over the speed range from 8 to 12 mph can reach values of 0.2 g at the pitch axis (CG) and 0.25 g at the driver's station. The LVTP-7 results are compared with the FLASH pitch axis accelerations since the longitudinal positions of the accelerometers in both vehicles as a percentage of the length are more closely related. The LVTP-7 results are 0.03 to 0.05 g lower than those of the small amphibian.

At the design load of 14 tons, the configuration with the dead-rise bow flap extended at 35 degrees operated successfully at either track position over the entire speed range in both calm water and waves. This was also true for the light load in the tracks down position. At the light load with tracks up, the model amphibian experienced some difficulty at 8 mph; it submerged its bow.

Raising the bow flap to 45 degrees (no gap) and to its fully extended position (Run 79, Table 5) solved the bow immersion problem but introduced the matter of driver visibility. Since it was thought that the tangent plate (which would not be present on the prototype) might be trapping water, the plate was removed and the configuration rerun at 8 mph. The same behavior with the bow submerging occurred.

In order to find out why the light load condition in waves ran well with tracks extended and yet submerged its bow when the tracks were retracted, additional calm water tests were conducted. It became obvious that at 8 mph, the tracks down configuration ran at 0.5 degrees higher running trim than with the tracks up, 3.8 vs. 3.2 degrees (Run 12 compared with Run 38, in Tables 1.1 and 1.2). The immersion problem is therefore a matter of the mean running trim and appears to be very sensitive to it at the light load. The higher running trims associated with the aft CG at the design load accounts for the satisfactory performance of this condition.

Additional trials were run in calm water (tracks retracted) to see if some combinations of parameters not previously tested would submerge the bow. Results indicated that if the bow flap was run at 35 degrees (with gap), the bow stayed up. When the bow flap was run at 45 degrees (without gap) then both the 12.8 and 14 ton loads with deadrise submerged their bows at 8 mph in calm water. Removing the

deadrise portion with the flap at 45 degrees, also caused the 12.8 ton load to submerge its bow, this time at the lower speed of 6 mph.

The configuration of the design load, with tracks up and wheel covers in place, operated successfully in both calm and rough water with the deadrise bow flap at 35 degrees. This configuration has the least drag and minimum deck wetness. For the light load forward CG condition, which immersed its bow at 8 mph, there are a number of options open to prevent this behavior. These could be used individually or in combination: lower the tracks; increase the bow flap extension and increase its slope; move the CG further aft; and finally, limit speed of this configuration to 7 mph.

CONCLUDING REMARKS AND RECOMMENDATIONS

A small tracked amphibian (FLASH) was tested over a range of speeds, at two loading conditions, and with various track and bow flap configurations. In addition to describing the model, apparatus, and test techniques, the report presents and analyzes the data. A discussion of the results includes a performance comparison with the large 26 ton amphibian, the LVTP-7, in order to put the FLASH data in perspective.

The calm water performance shows the drag/ton increasing with speed particularly beyond 8 mph. Reductions in the calm water resistance can be realized by retracting the wheel-track suspension and streamlining the wheels with covers. At 8 mph, for example, retracting the tracks reduces the drag by 14 percent. Wheel covers reduce the drag by another 5 percent. Added resistance in waves (Sea State 2) however increases the calm water values by 30 percent at this speed. Bow flap configuration and load have an insignificant effect on the drag per short ton, despite rather large changes in the running trim.

Significant accelerations are below 0.3 g at the driver's station with reductions further aft along the hull. The average 1/3 highest (significant) double amplitude motions can be as high as 2 ft of heave at the CG and 16 degrees of pitch at 8 mph.

The design load condition (14 ton) with tracks up and with the deadrise bow sloped at 35 degrees should be the configuration to design to. It is the configuration with least drag/ton and deck wetness and operates successfully in both calm water and Sea State 2. The light load of 12.8 tons with its corresponding forward CG shift creates a bow immersion problem at 8 mph in Sea State 2. This behavior can be prevented by either lowering the tracks, extending the length or increasing the slope of the bow flap, shifting the CG further aft or limiting the speed to 7 mph.

Generally, the behavior of the 14 ton vehicle FLASH with its bow flap extended appears to be a successful design of a low-freeboard tracked amphibian.

TABLE 1.1

CALM WATER PERFORMANCE

Displacement 25,600 lb, LCG 104.3 inches

Tracks Extended, Various Bow Flap Configurations

Wheel Covers Off

RUN	LOAD s-ton	SPEED mph	DRAFT ft	TRIM deg	DRAG lb	DRAG/LOAD lb/s-ton
Bow Flap with Deadrise, No Gap						
7	12.8	0.00	3.56	0.00	0.	0.
2	12.8	2.00	3.60	0.13	180.	14.
3	12.8	4.00	3.69	0.45	730.	57.
4	12.8	6.00	3.85	1.08	1,830.	143.
5	12.8	8.00	4.12	1.92	3,890.	304.
9	12.8	8.00	4.13	1.34	3,970.	310.
6	12.8	10.00	4.30	6.20	7,670.	599.
8	12.8	12.00	4.17	13.64	14,840.	1,160.
Bow Flap with Deadrise, and Gap						
10	12.8	0.00	3.51	- 0.49	0.	0.
30	12.8	0.00	3.50	- 0.31	0.	0.
11	12.8	6.00	3.85	1.42	1,900.	148.
12	12.8	8.00	4.04	3.84	3,830.	299.
13	12.8	10.00	4.19	7.69	7,870.	615.
14	12.8	10.34	4.12	8.64	8,710.	681.
15	12.8	12.00	4.00	13.57	14,320.	1,119.
Bow Flap without Deadrise, No Gap						
28	12.8	0.00	3.56	- 1.42	0.	0.
29	12.8	4.01	3.69	- 0.77	830.	65.
31	12.8	6.00	3.82	0.31	1,920.	150.
32	12.8	8.00	4.04	2.14	3,940.	308.
33	12.8	10.00	4.36	5.64	7,970.	623.

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TABLE 1.2

CALM WATER PERFORMANCE

Displacement 25,600 lb, LCG 104.3 inches

Tracks Retracted, Various Bow Flap Configurations

RUN	LOAD s-ton	SPEED mph	DRAFT ft	TRIM deg	DRAG lb	DRAG/LOAD lb/s-ton
Bow Flap with Deadrise, and Gap, Wheel Covers Off						
34	12.8	0.00	3.63	- 0.55	0.	0.
35	12.8	2.01	3.65	- 0.34	180.	14.
36	12.8	4.01	3.73	0.24	680.	53.
37	12.8	5.99	3.88	1.09	1,650.	129.
38	12.8	8.00	4.08	3.17	3,310.	258.
39	12.8	10.00	4.22	7.15	6,310.	493.
40	12.8	12.00	4.21	12.77	12,420.	971.
Bow Flap without Deadrise, with Gap Wheel Covers Off						
53	12.8	0.00	3.67	- 1.54	0.	0.
57	12.8	0.00	3.65	- 1.55	0.	0.
58	12.8	0.00	3.66	- 1.56	0.	0.
54	12.8	4.01	3.78	- 0.49	750.	58.
55	12.8	6.00	3.90	0.47	1,780.	139.
56	12.8	8.00	4.12	2.51	3,470.	271.
59	12.8	10.00	4.27	6.57	6,550.	512.
60	12.8	12.00	4.27	12.10	12,350.	965.
Bow Flap with Deadrise, and Gap Wheel Covers On						
-	12.8	0.00	3.55	- 0.57	0.	0.
73	12.8	6.00	3.80	-	1,690.	132.
71	12.8	8.00	4.04	-	3,120.	244.
74	12.8	10.00	4.07	7.18	6,040.	472.
72	12.8	12.00	4.01	-	11,360.	887.

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TABLE 1.2
(Continued)

RUN	LOAD s-ton	SPEED mph	DRAFT ft	TRIM deg	DRAG lb	DRAG/LOAD lb/s-ton
Bow Flap with Deadrise, No Gap Wheel Covers On						
108	12.8	0.00	3.47	- 0.15	0.	0.
109	12.8	5.99	3.80	- 0.08	1,540.	120.
110*	12.8	8.00	-	-	-	-
Bow Flap without Deadrise, with Gap Wheel Covers On						
61	12.8	0.00	3.51	- 1.93	0.	0.
102	12.8	0.00	3.57	- 1.69	0.	0.
62	12.8	4.01	3.67	- 0.78	750.	58.
63	12.8	6.00	3.78	0.02	1,740.	136.
103	12.8	5.99	3.81	0.19	1,770.	139.
64	12.8	8.00	4.03	2.10	3,320.	260.
104	12.8	8.00	4.03	2.16	3,300.	258.
65	12.8	10.00	4.19	6.11	6,380.	498.
105	12.8	10.00	4.17	5.98	6,160.	481.
66	12.8	12.00	4.15	11.20	11,780.	921.
Bow Flap without Deadrise, No Gap Wheel Covers On						
106	12.8	0.00	3.58	- 1.61	0.	0.
107*	12.8	6.00	4.28	- 8.87	3,130.	244.

* Bow Submerged

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TABLE 2.1

CALM WATER PERFORMANCE

Displacement 28,000 lb, LCG 107.9 inches
Tracks Extended, Various Bow Flap Configurations
Wheel Covers Off

RUN	LOAD s-ton	SPEED mph	DRAFT ft	TRIM deg	DRAG lb	DRAG/LOAD lb/s-ton
Bow Flap with Deadrise, and Gap						
16	14.00	0.00	3.75	2.06	0.	0.
17	14.00	4.01	3.97	2.80	840.	60.
18	14.00	5.99	4.06	4.01	2,040.	146.
19	14.00	8.00	4.29	6.55	4,530.	324.
20	14.00	10.00	4.45	11.07	9,270.	662.
21	14.00	12.00	4.23	16.89	16,280.	1,163.
Bow Flap with Deadrise, No Gap						
22	14.00	0.00	3.83	1.47	0.	0.
23	14.00	4.01	3.99	2.02	850.	61.
24	14.00	6.00	4.14	3.04	2,090.	149.
25	14.00	8.00	4.31	4.94	4,280.	306.
26	14.00	10.00	4.48	8.85	8,680.	620.
27	14.00	12.00	4.50	15.85	16,810.	1,201.

TR-2250

TABLE 2.2

CALM WATER PERFORMANCE

Displacement 28,000 lb, LCG 107.9 inches

Tracks Retracted, Various Bow Flap Configurations

RUN	LOAD s-ton	SPEED mph	DRAFT ft	TRIM deg	DRAG lb	DRAG/LOAD lb/s-ton
Bow Flap with Deadrise, and Gap Wheel Covers Off						
41	14.00	0.00	3.91	2.08	0.	0.
42	14.00	4.01	4.01	2.70	730.	52.
43	14.00	5.99	4.15	3.64	1,750.	125.
44	14.00	8.00	4.35	5.81	3,660.	261.
45	14.00	10.00	4.43	9.86	7,270.	519.
46	14.00	12.00	4.42	15.73	14,160.	1,012.
Bow Flap without Deadrise, with Gap Wheel Covers Off						
47	14.00	0.00	3.95	1.23	0.	0.
48	14.00	4.01	4.07	2.12	810.	58.
49	14.00	6.00	4.21	3.22	1,880.	135.
50	14.00	8.00	4.40	5.36	3,780.	270.
51	14.00	10.00	4.49	9.17	7,290.	521.
52	14.00	12.00	4.53	15.53	14,440.	1,032.
Bow Flap with Deadrise, and Gap Wheel Covers On						
-	14.00	0.00	3.78	1.72	0.	0.
86	14.00	6.00	4.04	3.43	1,950.	140.
91	14.00	8.00	4.22	5.87	3,570.	255.
98	14.00	8.00	4.15	5.29	3,490.	249.
92	14.00	10.00	4.24	10.19	6,340.	452.

TR-2250

TABLE 2.2
(Continued)

RUN	LOAD s-ton	SPEED mph	DRAFT ft	TRIM deg	DRAW lb	DRAW/LOAD lb/s-ton
Bow Flap with Deadrise, No Gap Wheel Covers On						
94	14.00	0.00	3.71	2.32	0.	0.
95	14.00	6.00	3.97	3.08	1,670.	119.
96*	14.00	8.00	-	-	-	-
97*	14.00	8.00	-	-	-	-
Bow Flap without Deadrise, with Gap Wheel Covers On						
-	14.00	0.00	3.85	1.13	0.	0.
99	14.00	6.00	4.12	2.91	1,830.	131.
100	14.00	8.00	4.31	5.10	3,600.	257.
101	14.00	10.00	4.38	8.52	6,730.	481.

* Bow Submerged

TR-2250

TABLE 3.1

IRREGULAR WAVE STATISTICS

Displacement 25,600 lb, LCG 104.3 inches

Tracks Extended with Wheel Covers On

Bow Flap with Deadrise and Gap

DAVIDSON LABORATORY

11-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 121

SPEED 6.0 MPH
WEIGHT 12.8 S-TONS
DRAG 191. LB/S-TON

WAVE ENCOUNTERS 56
SEA STATE 2
LCG 104.3 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	1.394	43	6.53	9.20	10.76	12.59
	3.954	1.10	-3.51	-6.04	-7.26	-8.38
HEAVE, FT	-1.659	37	-1.03	-0.64	-0.28	-0.07
	0.545	0.10	-2.29	-2.66	-2.86	-3.06
DRIVER, ACC	-0.007	49	0.14	0.21	0.28	0.43
	0.101	0.10	-0.15	-0.25	-0.32	-0.43
C G ACC, G	0.005	40	0.13	0.18	0.21	0.22
	0.085	0.10	-0.12	-0.17	-0.23	-0.29

TR-2250

TABLE 3.2

DAVIDSON LABORATORY

11-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 123

SPEED 10.0 MPH
WEIGHT 12.8 S-TONS
DRAG 702. LB/S-TON

WAVE ENCOUNTERS 41
SEA STATE 2
LCG 104.3 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	9.715	28	14.19	16.42	17.59	18.15
	3.525	1.10	4.96	3.25	1.57	0.18
HEAVE, FT	-2.074	27	-1.59	-1.23	-0.92	-0.75
	0.441	0.10	-2.58	-2.92	-3.14	-3.39
DRIVER, ACC	-0.018	34	0.15	0.22	0.25	0.27
	0.125	0.10	-0.21	-0.30	-0.35	-0.36
C G ACC, G	0.007	27	0.15	0.21	0.27	0.32
	0.096	0.10	-0.13	-0.19	-0.23	-0.24

TR-2250

TABLE 4.1

IRREGULAR WAVE STATISTICS

Displacement 25,600 lb, LCG 104.3 inches
Tracks Retracted with Wheel Covers On
Bow Flap with Deadrise and Gap

DAVIDSON LABORATORY

SMALL AMPHIBIAN (FLASH)

9-DEC-81

RUN 75

SPEED 4.0 MPH
WEIGHT 12.8 S-TONS
DRAG 92. LB/S-TON

WAVE ENCOUNTERS 70
SEA STATE 2
LCG 104.3 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	0.320 4.230	58 1.10	5.88 -5.44	8.57 -7.93	10.36 -9.77	12.15 -10.87
HEAVE, FT						
DRIVER, ACC	-0.014 0.082	68 0.10	0.11 -0.13	0.17 -0.21	0.23 -0.26	0.37 -0.34
C G ACC, G	0.002 0.072	50 0.10	0.11 -0.11	0.16 -0.15	0.18 -0.18	0.19 -0.23

TR-2250

TABLE 4.2

DAVIDSON LABORATORY

9-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 76

	SPEED	6.0 MPH					WAVE ENCOUNTERS	53
	WEIGHT	12.8 S-TONS					SEA STATE	2
	DRAG	198. LB/S-TON					LCG	104.3 IN
	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME		
PITCH, DEG	1.129	41	6.21	9.02	11.22	12.83		
	3.922	1.10	-4.00	-6.28	-7.25	-8.54		
HEAVE, FT								
DRIVER, ACC	-0.009	54	0.13	0.20	0.27	0.41		
	0.098	0.10	-0.14	-0.24	-0.31	-0.39		
C G ACC, G	0.003	39	0.13	0.19	0.23	0.24		
	0.088	0.10	-0.13	-0.19	-0.22	-0.28		

TABLE 4.3

DAVIDSON LABORATORY

SMALL AMPHIBIAN (FLASH)

10-DEC-81

RUN 80

	SPEED	7.0 MPH			WAVE ENCOUNTERS	47
	WEIGHT	12.8 S-TONS			SEA STATE	2
	DRAG	241. LB/S-TON			LCG	104.3 IN
	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	2.112	36	6.99	9.21	11.34	13.04
	3.689	1.10	-2.78	-5.22	-6.24	-7.11
HEAVE, FT	-1.710	34	-1.14	-0.76	-0.55	-0.09
	0.493	0.10	-2.31	-2.65	-2.89	-3.19
DRIVER, ACC	-0.009	41	0.15	0.21	0.25	0.38
	0.100	0.10	-0.15	-0.24	-0.32	-0.36
C G ACC, G	-0.003	35	0.14	0.18	0.22	0.24
	0.091	0.10	-0.13	-0.19	-0.24	-0.26

Note: At 8.0 mph bow, submerged; and run was aborted. Same behavior occurred at 8.0 mph with tangent plate removed.

TABLE 5

IRREGULAR WAVE STATISTICS

Displacement 25,600 lb, LCG 104.3 inches

Tracks Retracted with Wheel Covers On

Bow Flap with Deadrise, No Gap, and

Elevated to Maximum Up Position

DAVIDSON LABORATORY

9-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 79

SPEED 8.0 MPH
 WEIGHT 12.8 S-TONS
 DRAG 351. LB/S-TON

WAVE ENCOUNTERS 44
 SEA STATE 2
 LCG 104.3 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	2.149	32	7.43	9.54	11.35	12.92
	3.824	1.10	-3.30	-5.10	-6.30	-6.67
HEAVE, FT						
DRIVER, ACC	-0.008	42	0.15	0.24	0.30	0.46
	0.109	0.10	-0.16	-0.23	-0.27	-0.36
C G ACC, G	0.001	32	0.15	0.22	0.26	0.29
	0.099	0.10	-0.14	-0.20	-0.24	-0.26

TR-2250

TABLE 6.1

IRREGULAR WAVE STATISTICS

Displacement 28,000 lb, LCG 107.9 inches

Tracks Extended with Wheel Covers On

Bow Flap with Deadrise and Gap

DAVIDSON LABORATORY

14-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 130

SPEED 6.0 MPH
WEIGHT 14.0 S-TONS
DRAG 192. LB/S-TON

WAVE ENCOUNTERS 54
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	4.372 4.153	42 1.10	9.91 -0.71	12.43 -3.22	13.79 -4.62	14.58 -6.03
HEAVE, FT	-1.954 0.521	37 0.10	-1.32 -2.56	-0.94 -2.88	-0.63 -3.17	-0.20 -3.48
DRIVER, ACC	-0.011 0.111	53 0.10	0.14 -0.16	0.21 -0.26	0.28 -0.34	0.41 -0.39
C G ACC, G	-0.002 0.082	39 0.10	0.12 -0.13	0.16 -0.19	0.19 -0.24	0.24 -0.28

TR-2250

TABLE 6.2

DAVIDSON LABORATORY

14-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 131

	SPEED 8.0 MPH				WAVE ENCOUNTERS 47	
	WEIGHT 14.0 S-TONS				SEA STATE 2	
	DRAG 377. LB/S-TON				LCG 107.9 IN	
	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	7.257	33	12.66	15.73	17.39	18.30
	4.249	1.10	1.65	-0.49	-1.30	-1.78
HEAVE, FT	-2.192	32	-1.60	-1.15	-0.87	-0.57
	0.525	0.10	-2.77	-3.14	-3.45	-3.67
DRIVER, ACC	-0.015	39	0.16	0.25	0.34	0.57
	0.124	0.10	-0.19	-0.28	-0.37	-0.39
C G ACC, G	-0.000	33	0.14	0.20	0.22	0.23
	0.096	0.10	-0.14	-0.20	-0.24	-0.25

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TABLE 6.3

DAVIDSON LABORATORY

14-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 132

SPEED 10.0 MPH
WEIGHT 14.0 S-TONS
DRAG 727. LB/S-TON

WAVE ENCOUNTERS 39
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	12.809 3.892	30 1.10	17.45 8.03	20.07 5.60	21.19 4.67	22.25 3.49
HEAVE, FT	-2.303 0.449	25 0.10	-1.78 -2.84	-1.46 -3.17	-1.21 -3.45	-0.83 -3.51
DRIVER, ACC	-0.026 0.131	35 0.10	0.16 -0.20	0.23 -0.29	0.27 -0.32	0.33 -0.33
C G ACC, G	0.001 0.095	30 0.10	0.14 -0.13	0.21 -0.19	0.24 -0.23	0.26 -0.25

TR-2250

TABLE 7.1

IRREGULAR WAVE STATISTICS

Displacement 28,000 lb, LCG 107.9 inches

Tracks Retracted with Wheel Covers On

Bow Flap with Deadrise and Gap

DAVIDSON LABORATORY

10-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 82

SPEED 4.0 MPH
WEIGHT 14.0 S-TONS
DRAG 134. LB/S-TON

WAVE ENCOUNTERS 70
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	3.589	57	9.73	12.77	14.99	17.10
	4.622	1.10	-2.67	-5.36	-6.65	-8.19
HEAVE, FT	-1.729	51	-1.06	-0.70	-0.48	-0.15
	0.532	0.10	-2.40	-2.76	-2.93	-3.11
DRIVER, ACC	-0.014	66	0.13	0.18	0.24	0.48
	0.096	0.10	-0.15	-0.24	-0.27	-0.30
C G ACC, G	0.002	51	0.11	0.15	0.17	0.19
	0.071	0.10	-0.11	-0.15	-0.17	-0.20

TR-2250

TABLE 7.2

DAVIDSON LABORATORY

10-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 83

SPEED 6.0 MPH
WEIGHT 14.0 S-TONS
DRAG 215. LB/S-TON

WAVE ENCOUNTERS 56
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	4.716	41	10.14	12.71	13.90	15.54
	4.166	1.10	-0.93	-3.16	-4.60	-5.44
HEAVE, FT	-1.925	39	-1.31	-0.92	-0.75	-0.41
	0.515	0.10	-2.54	-2.92	-3.29	-3.45
DRIVER, ACC	-0.014	64	0.14	0.22	0.29	0.40
	0.107	0.10	-0.13	-0.24	-0.29	-0.35
C G ACC, G	0.002	40	0.12	0.17	0.21	0.25
	0.081	0.10	-0.12	-0.18	-0.20	-0.22

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TABLE 7.3

DAVIDSON LABORATORY

10-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 84

SPEED 7.0 MPH
WEIGHT 14.0 S-TONS
DRAG 274. LB/S-TON

WAVE ENCOUNTERS 46
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	5.713 4.014	37 1.10	11.03 0.62	13.42 -1.89	15.05 -3.53	15.26 -4.36
HEAVE, FT	-2.067 0.527	35 0.10	-1.46 -2.68	-1.02 -3.06	-0.72 -3.38	-0.51 -3.58
DRIVER, ACC	-0.015 0.111	41 0.10	0.16 -0.18	0.23 -0.28	0.29 -0.35	0.55 -0.42
C G ACC, G	0.003 0.088	35 0.10	0.14 -0.12	0.19 -0.19	0.22 -0.23	0.23 -0.27

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TABLE 7.4

DAVIDSON LABORATORY

10-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 85

SPEED 8.0 MPH
WEIGHT 14.0 S-TONS
DRAG 359. LB/S-TON

WAVE ENCOUNTERS 45
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	7.028 4.068	32 1.10	12.54 1.44	15.04 -0.71	16.71 -1.89	17.38 -2.26
HEAVE, FT	-2.164 0.539	32 0.10	-1.55 -2.78	-1.12 -3.21	-0.85 -3.45	-0.46 -3.63
DRIVER, ACC	-0.017 0.116	45 0.10	0.16 -0.17	0.26 -0.26	0.38 -0.30	0.71 -0.35
C G ACC, G	0.004 0.097	34 0.10	0.15 -0.13	0.21 -0.19	0.25 -0.22	0.28 -0.26

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TABLE 7.5

DAVIDSON LABORATORY

10-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 87

SPEED 9.0 MPH
WEIGHT 14.0 S-TONS
DRAG 423. LB/S-TON

WAVE ENCOUNTERS 41
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG	8.843	34	13.99	16.71	18.84	20.06
	3.978	1.10	4.19	1.62	0.14	-0.75
HEAVE, FT	-2.226	33	-1.67	-1.22	-0.97	-0.79
	0.509	0.10	-2.76	-3.15	-3.44	-3.68
DRIVER, ACC	-0.017	49	0.15	0.25	0.34	0.50
	0.124	0.10	-0.16	-0.27	-0.33	-0.37
C G ACC, G	0.006	34	0.15	0.22	0.26	0.30
	0.100	0.10	-0.14	-0.20	-0.24	-0.24

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TABLE 7.6

DAVIDSON LABORATORY

10-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 88

SPEED 10.0 MPH
WEIGHT 14.0 S-TONS
DRAG 569. LB/S-TON

WAVE ENCOUNTERS 39
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AUG	1/3	1/10	EXTREME
PITCH, DEG	11.840	28	16.75	19.09	21.16	23.40
	3.944	1.10	6.74	4.41	2.91	1.75
HEAVE, FT	-2.246	26	-1.74	-1.42	-1.15	-0.63
	0.462	0.10	-2.78	-3.15	-3.38	-3.65
DRIVER, ACC	-0.026	37	0.16	0.24	0.28	0.31
	0.131	0.10	-0.20	-0.32	-0.38	-0.43
C G ACC, G	-0.002	30	0.14	0.22	0.27	0.31
	0.099	0.10	-0.14	-0.21	-0.26	-0.30

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TABLE 7.7

DAVIDSON LABORATORY

10-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 89

SPEED 11.0 MPH
WEIGHT 14.0 S-TONS
DRAG 748. LB/S-TON

WAVE ENCOUNTERS 47
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AUG	1/3	1/10	EXTREME
PITCH, DEG	15.199 3.763	35 1.10	19.52 10.83	22.08 8.52	23.25 7.17	6.02
HEAVE, FT	-2.239 0.408	35 0.10	-1.80 -2.62	-1.46 -2.92	-1.23 -3.23	-0.97 -3.52
DRIVER, ACC	-0.028 0.135	36 0.10	0.17 -0.23	0.25 -0.33	0.29 -0.38	0.34 -0.40
C G ACC, G	0.002 0.092	32 0.10	0.15 -0.14	0.21 -0.20	0.24 -0.25	0.27 -0.29

TR-2250

TABLE 7.8

DAVIDSON LABORATORY

10-DEC-81

SMALL AMPHIBIAN (FLASH)

RUN 90

SPEED 12.0 MPH
WEIGHT 14.0 S-TONS
DRAG 1031. LB/S-TON

WAVE ENCOUNTERS 35
SEA STATE 2
LCG 107.9 IN

	MEAN/RMS	OSC/BUFF	AVG	1/3	1/10	EXTREME
PITCH, DEG						
HEAVE, FT	-2.154 0.277	23 0.10	-1.85 -2.46	-1.66 -2.75	-1.49 -2.97	-1.30 -3.08
DRIVER, ACC	-0.045 0.120	29 0.10	0.15 -0.21	0.25 -0.29	0.30 -0.33	0.33 -0.36
C G ACC, G	-0.000 0.065	21 0.10	0.11 -0.11	0.17 -0.15	0.20 -0.18	0.23 -0.19

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TABLE 8
VIDEO SCENARIO

<u>RUN</u>	<u>FOOTAGE</u>	<u>RUN</u>	<u>FOOTAGE</u>	<u>RUN</u>	<u>FOOTAGE</u>	<u>RUN</u>	<u>FOOTAGE</u>
Titles	0	36	137	67	229	103	346
2	5	37	144	68	239	104	349
3	13	38	149	69	245	105	352
4	23	39	155	75	250	107	354
5	29	40	157	76	260	109	357
6	33	42	160	77	267	110	360
8	37	43	164	78	271	112	362
9	40	44	168	79	274	113	368
11	44	45	172	80	279	114	373
12	50	46	175	81	285	115	378
13	54	48	177	82	287	116	383
17	58	49	181	83	296	117	388
18	67	50	186	84	303	118	391
19	73	51	189	85	308**	119	395
20	77*	52	191	87	314	121	398
21	81	54	193	88	318	122	404
23	84	55	199	89	322	123	410
24	92	56	203	90	325	124	413
25	97	59	206	95	329	126	420
26	101	60	208	96	330	127	426
27	104	62	211	97	332	128	433
29	107	63	215	98	333	129	438
31	113	64	219	99	340	130	444
32	118	65	222	100	342	131	449
33	122	66	225	101	344	132	453
35	126						

Note: *Run 19 on Video

**Actual speed 7 mph, 8 mph on video

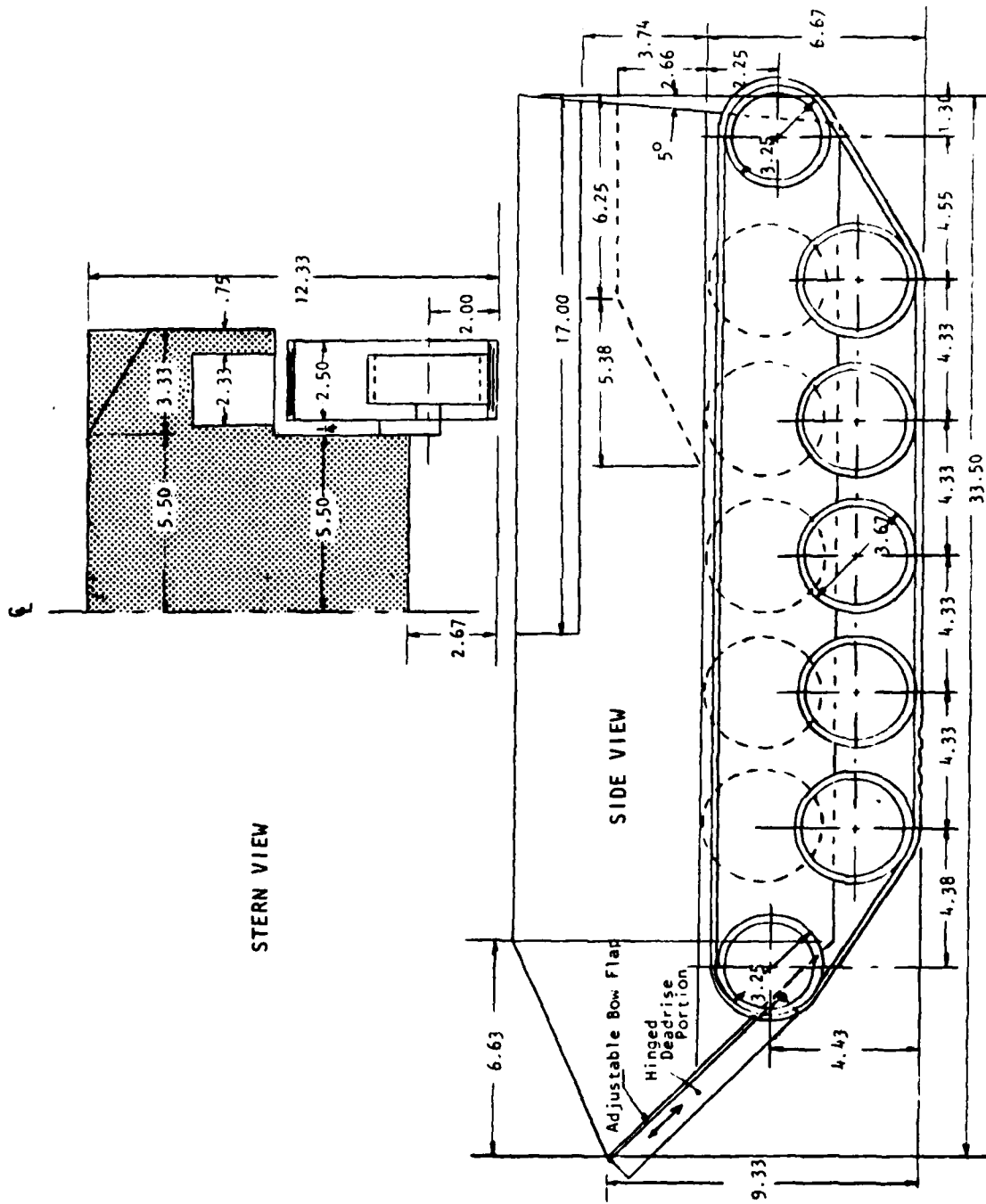


FIGURE 1 PRINCIPAL DIMENSIONS OF "FLASH" MODEL (INCHES)

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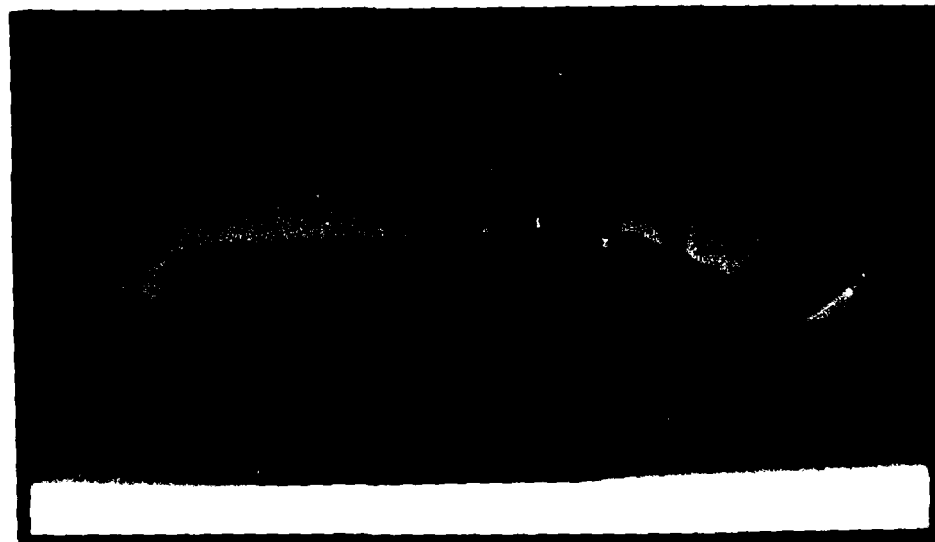


FIGURE 2 SMALL AMPHIBIAN MODEL-1/6 SCALE

TR-2250



**SPEED 6 MPH
BOW FLAP WITH DEADRISE, NO GAP**



**SPEED 10 MPH
BOW FLAP WITH DEADRISE AND GAP**

**FIGURE 3 SMALL AMPHIBIAN MODEL AT SPEED
28,000 LB. DISPLACEMENT**

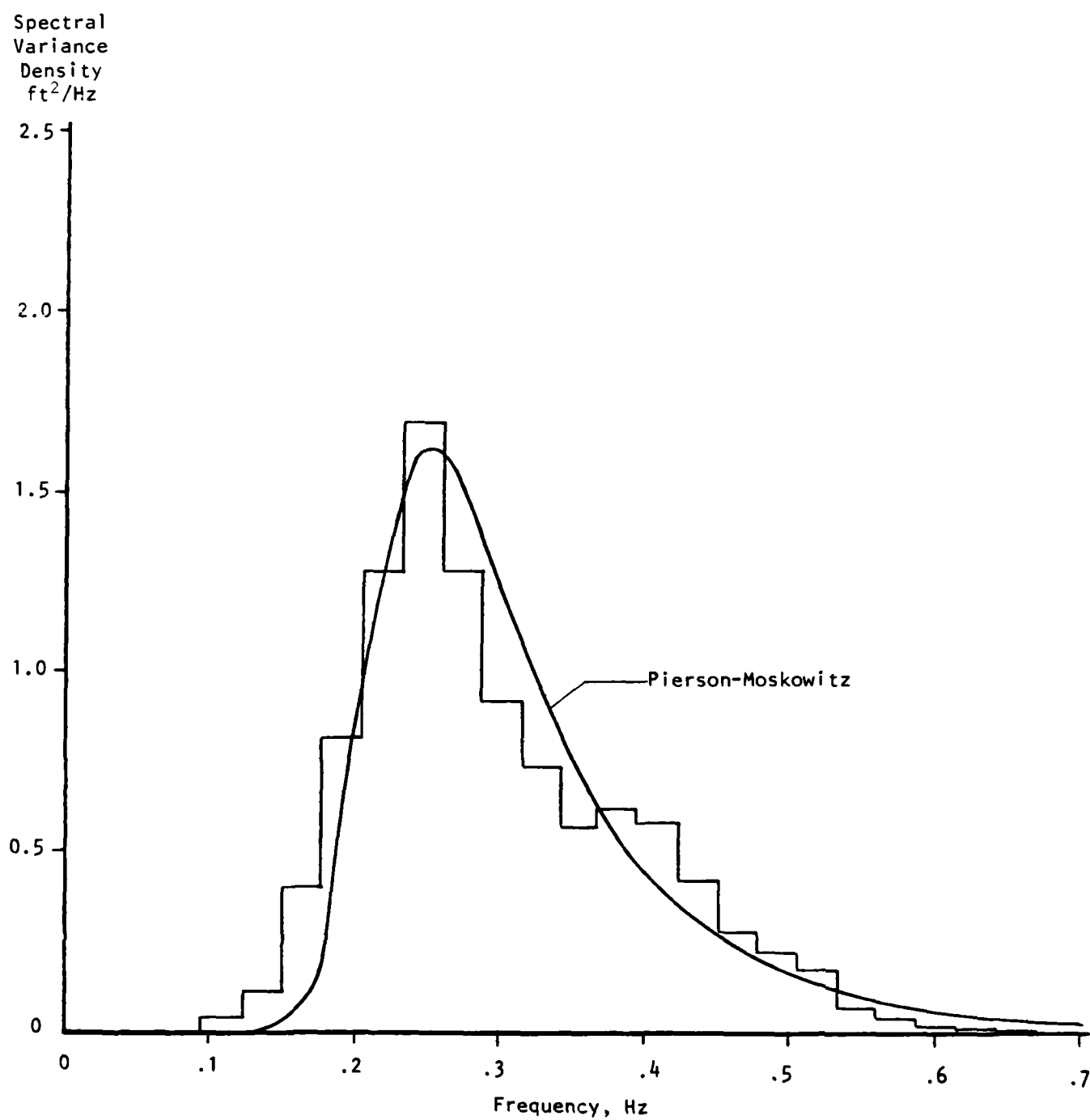


FIGURE 4 EXPERIMENTAL WAVE SPECTRUM, SIGNIFICANT HEIGHT 2.2 FT

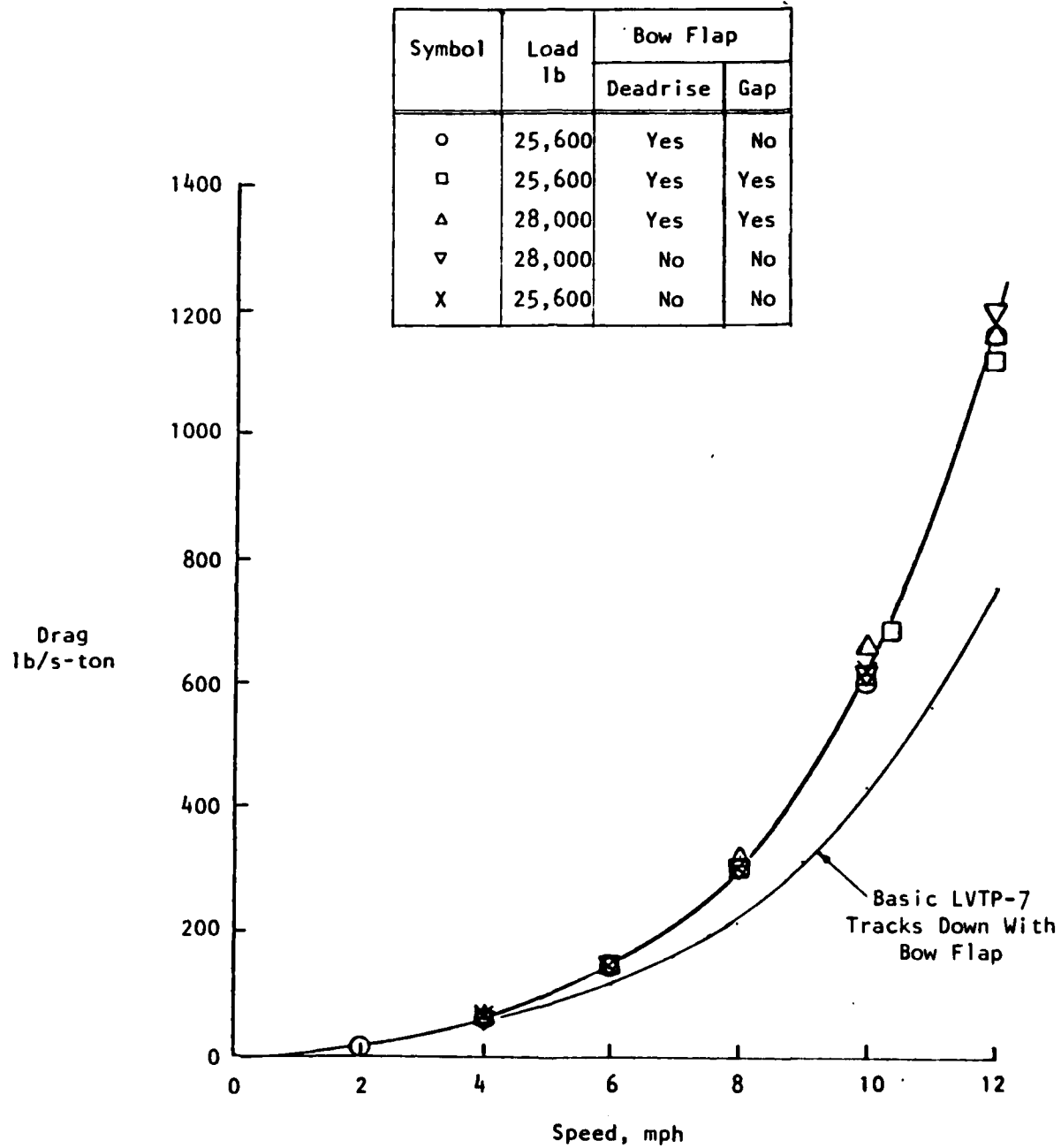


FIGURE 5 CALM WATER DRAG PERFORMANCE
TRACKS EXTENDED WITH WHEEL COVERS OFF

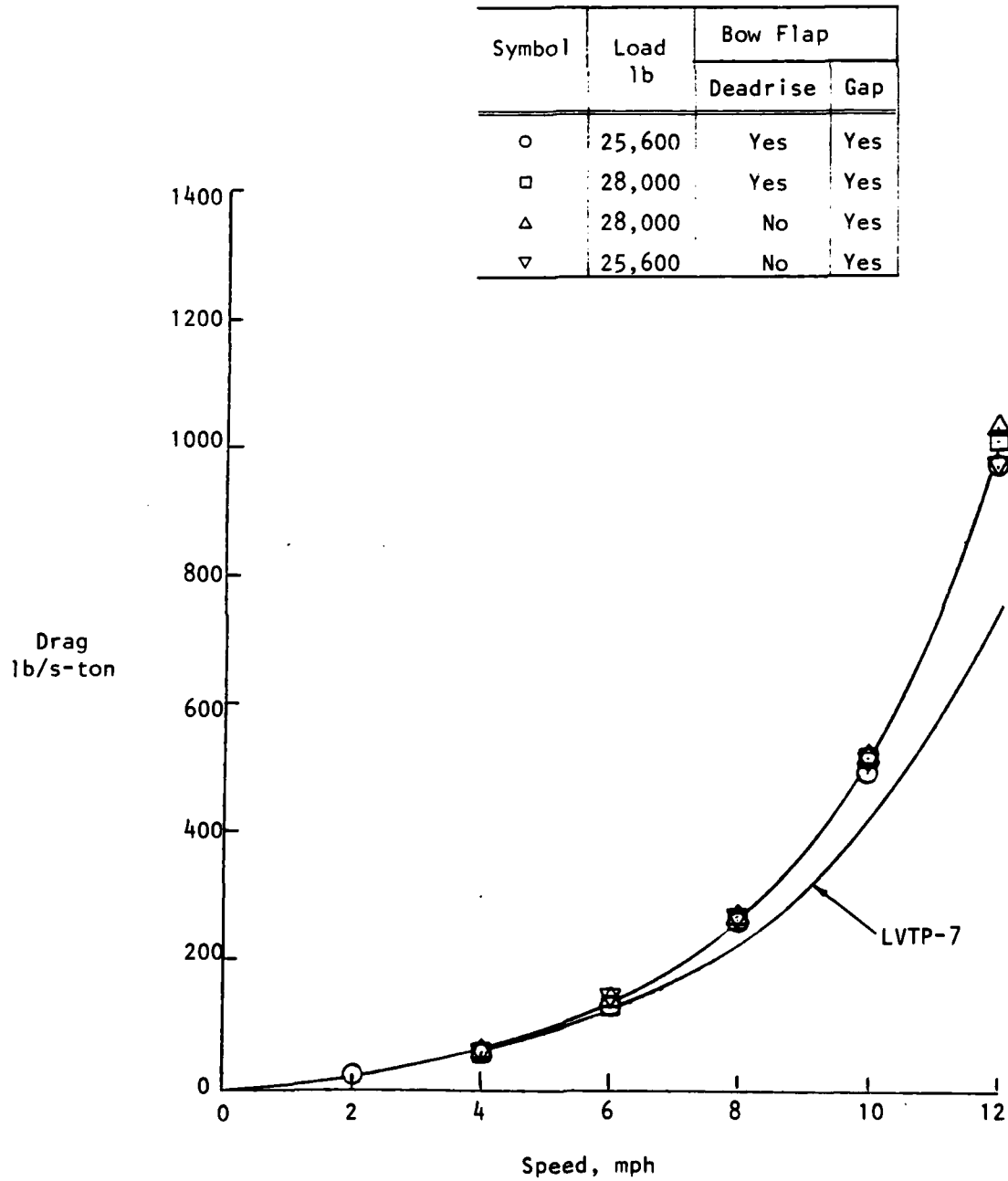


FIGURE 6 CALM WATER DRAG PERFORMANCE
TRACKS RETRACTED WITHOUT WHEEL COVERS

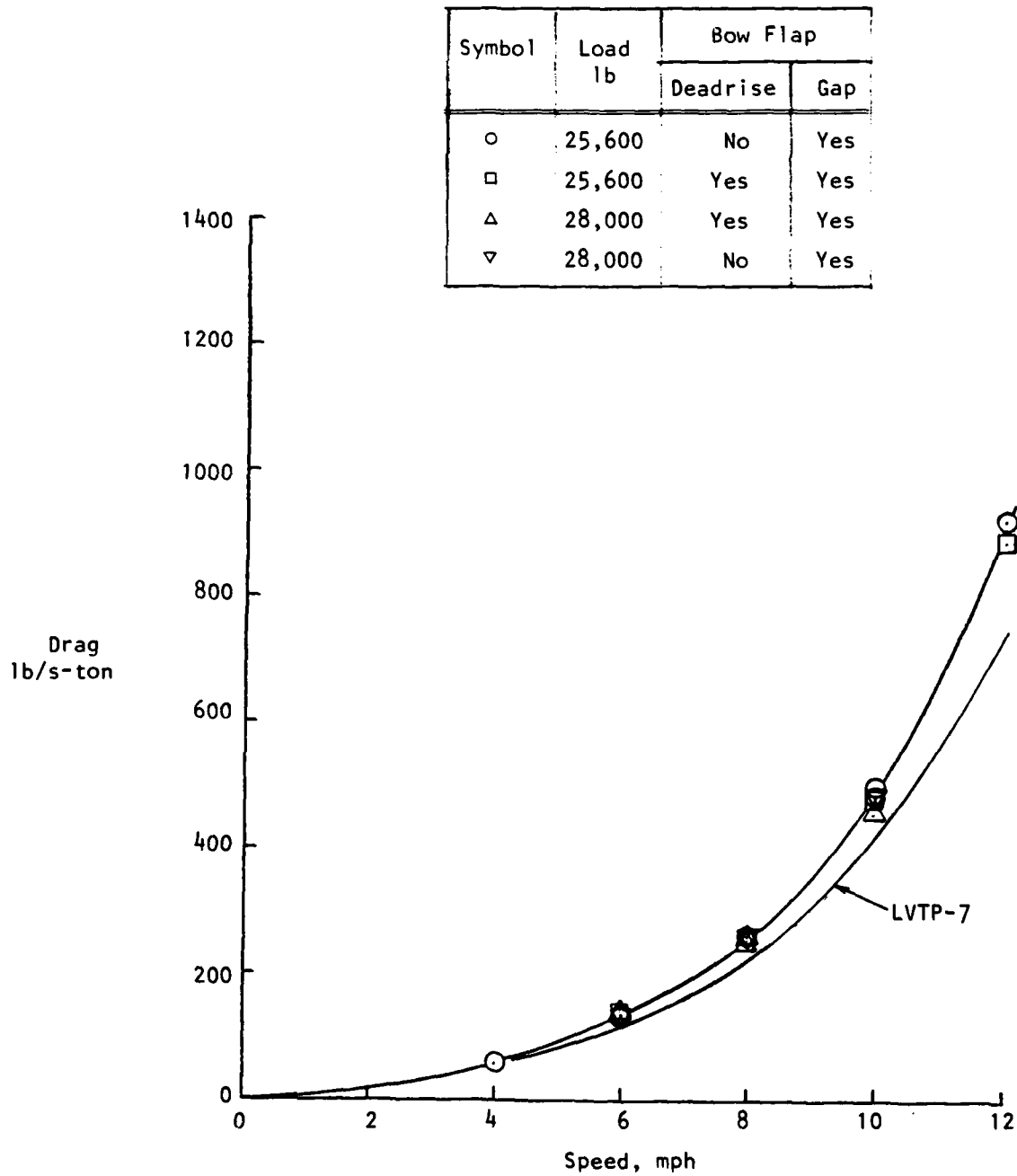


FIGURE 7 CALM WATER DRAG PERFORMANCE
TRACKS RETRACTED WITH WHEEL COVERS ON

Symbol	Load lb	Bow Flap	
		Deadrise	Gap
○	25,600	Yes	No
□	25,600	Yes	Yes
△	28,000	Yes	Yes
▽	28,000	No	No
X	25,600	No	No

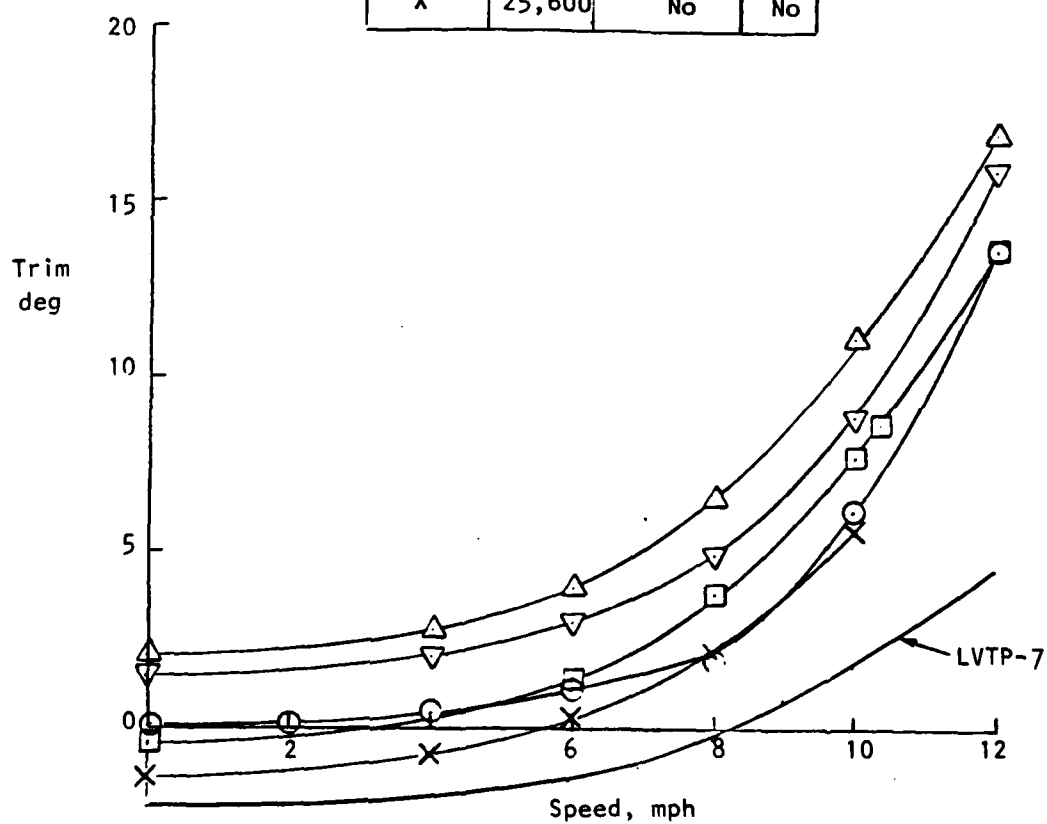


FIGURE 8 CALM WATER TRIM PERFORMANCE
TRACKS EXTENDED WITH WHEEL COVERS OFF

Symbol	Load lb	Bow Flap	
		Deadrise	Gap
○	25,600	Yes	Yes
□	28,000	Yes	Yes
△	28,000	No	Yes
▽	25,600	No	Yes

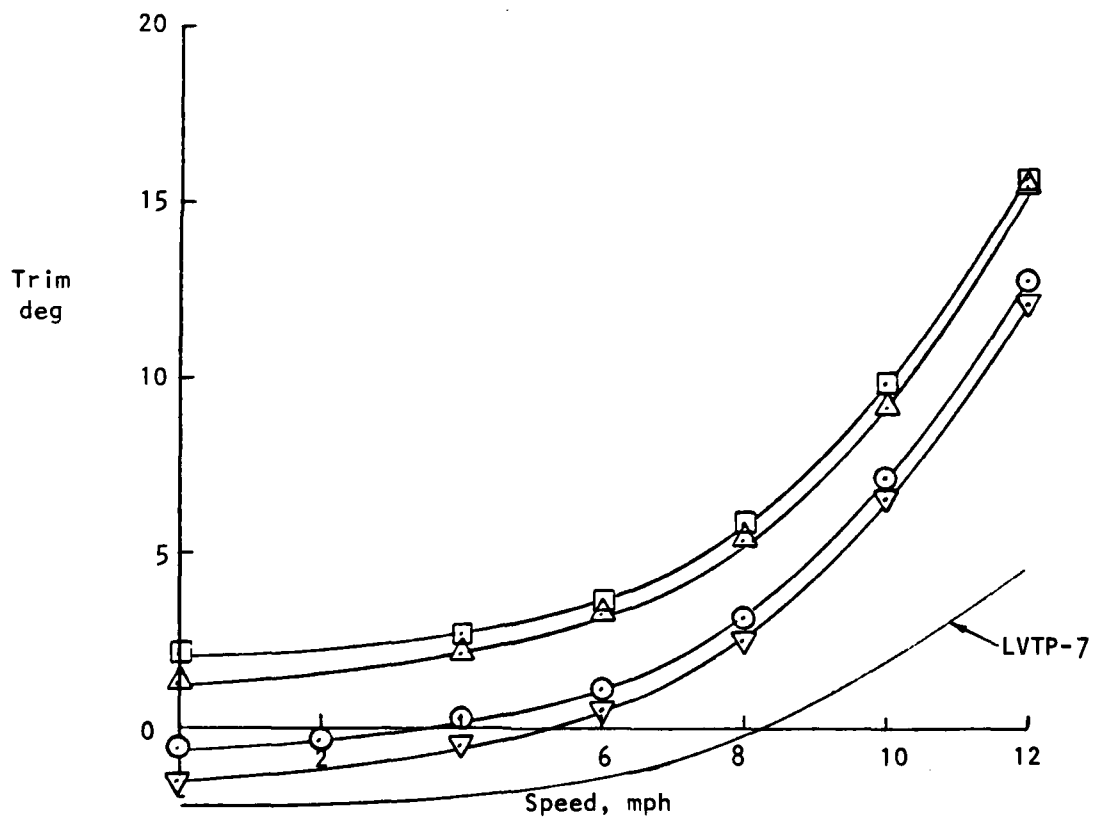


FIGURE 9 CALM WATER TRIM PERFORMANCE
TRACKS RETRACTED WITHOUT WHEEL COVERS

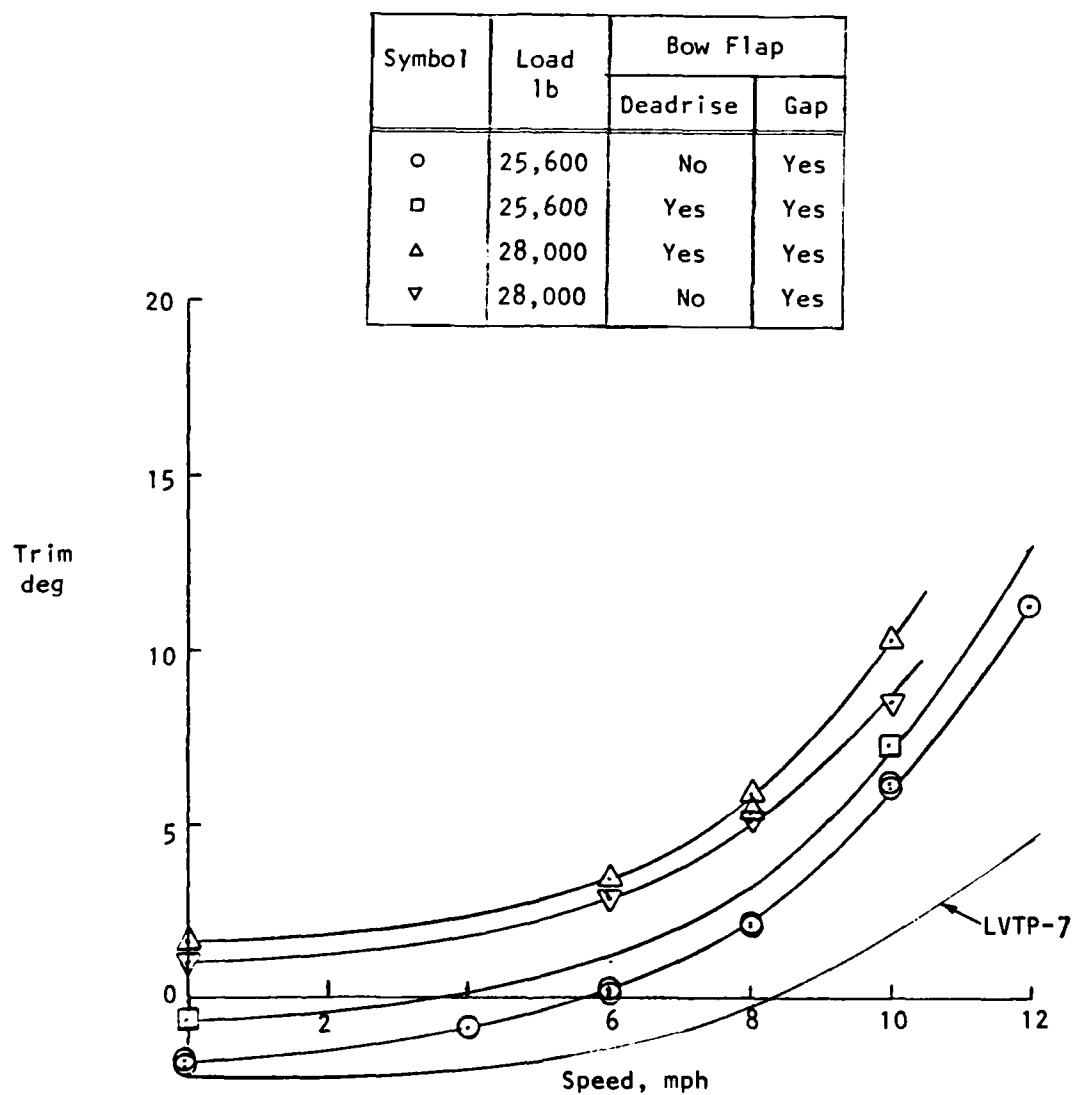


FIGURE 10 CALM WATER TRIM PERFORMANCE
TRACKS RETRACTED WITH WHEEL COVERS ON

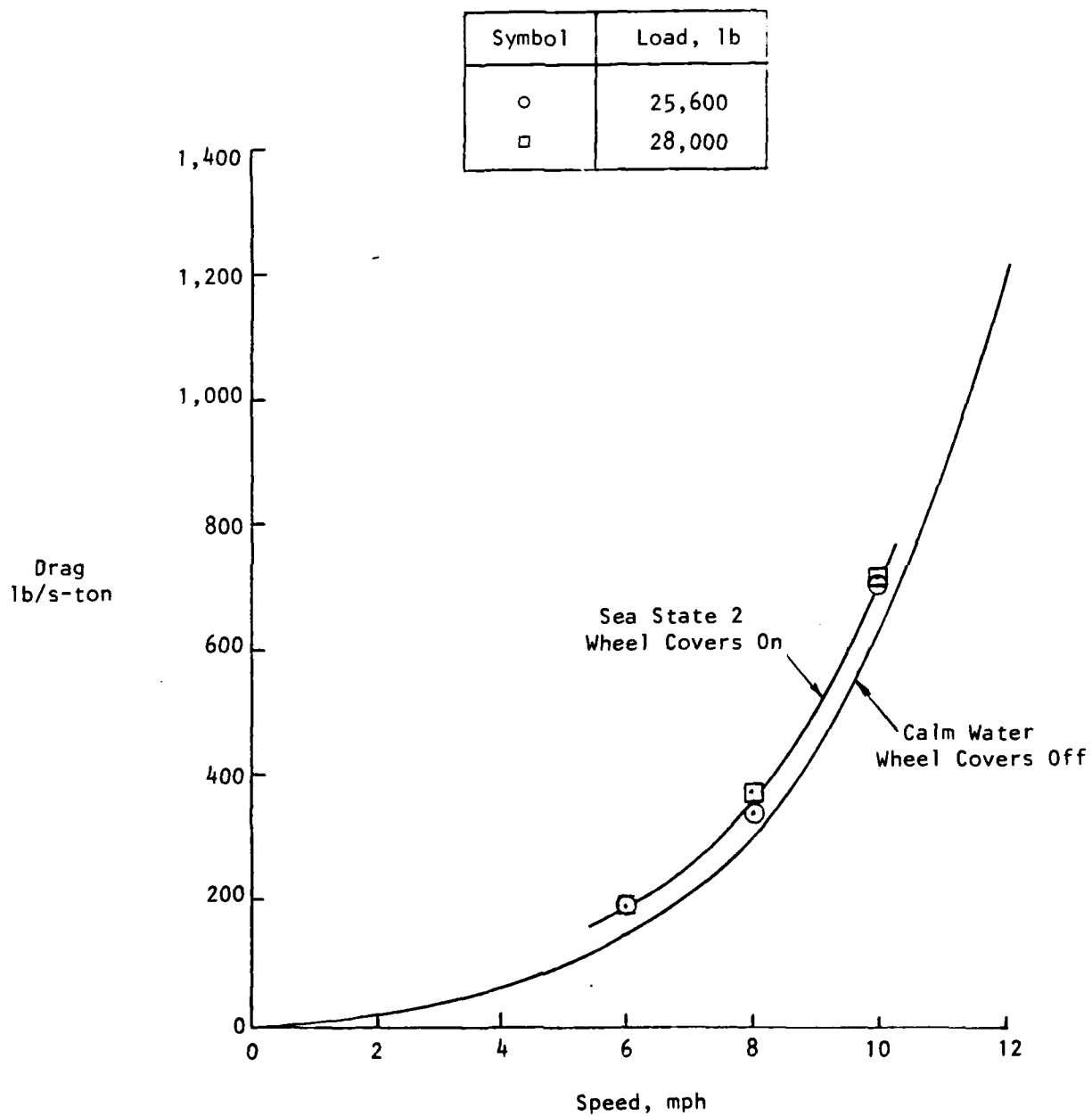


FIGURE 11 ROUGH WATER DRAG PERFORMANCE
TRACKS EXTENDED, BOW FLAP WITH DEADRISE AND GAP

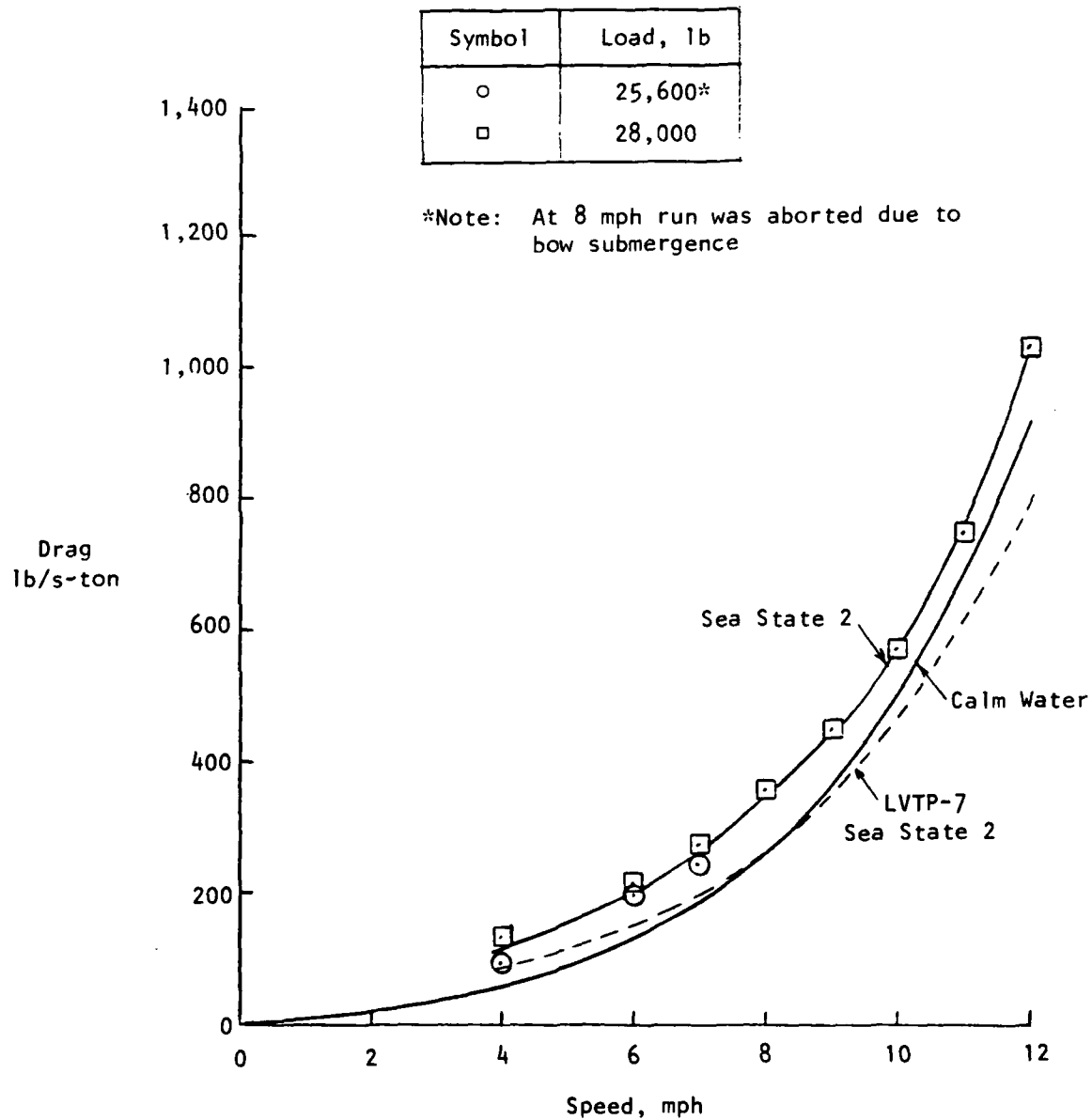


FIGURE 12 ROUGH WATER DRAG PERFORMANCE
TRACKS RETRACTED, WHEEL COVERS ON, BOW FLAP WITH DEADRISE AND GAP

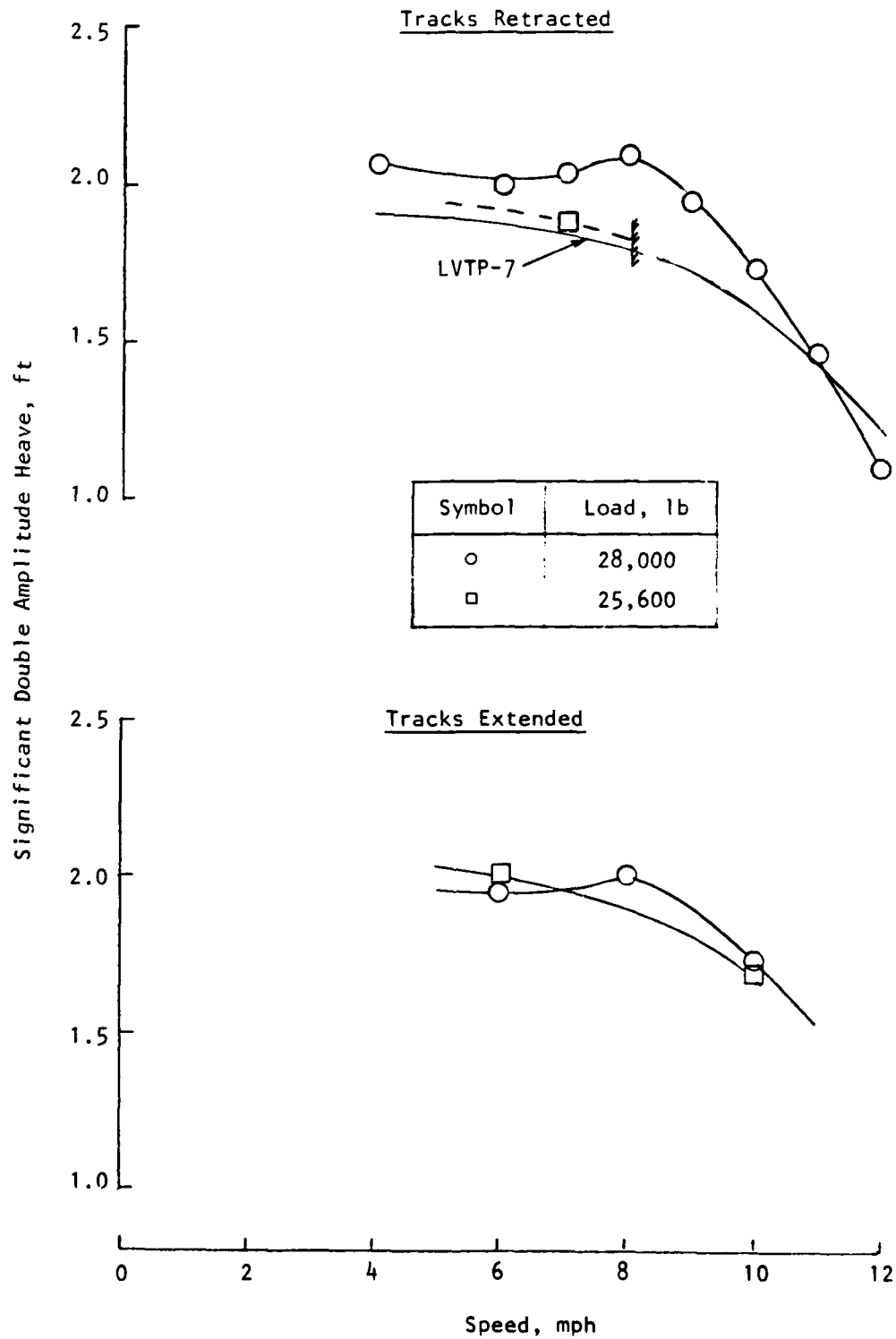


FIGURE 13 SIGNIFICANT HEAVE MOTIONS IN SEA STATE 2
BOW FLAP WITH DEADRISE AND GAP, WHEEL COVERS ON

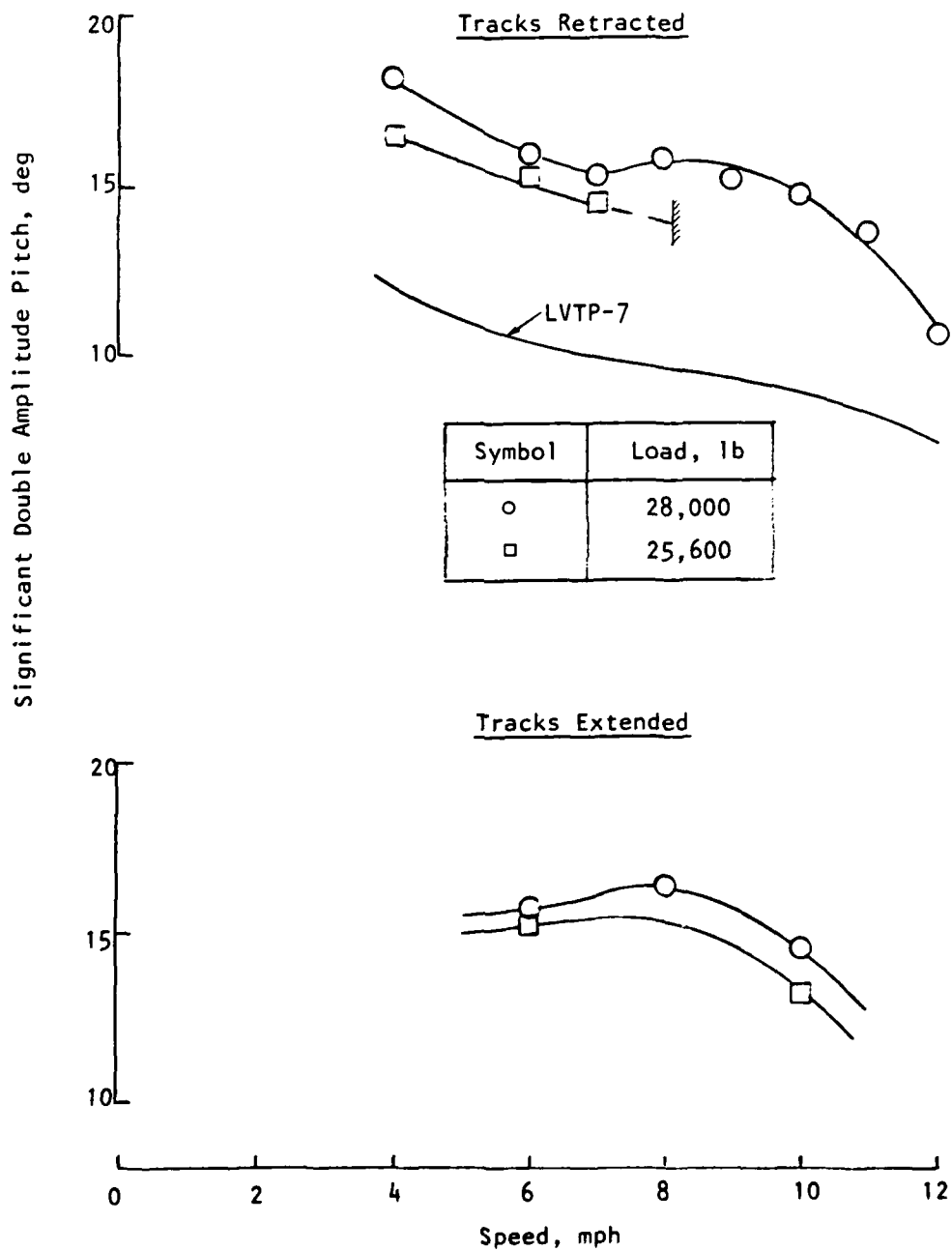


FIGURE 14 SIGNIFICANT PITCH MOTIONS IN SEA STATE 2
BOW FLAP WITH DEADRISE AND GAP, WHEEL COVERS ON

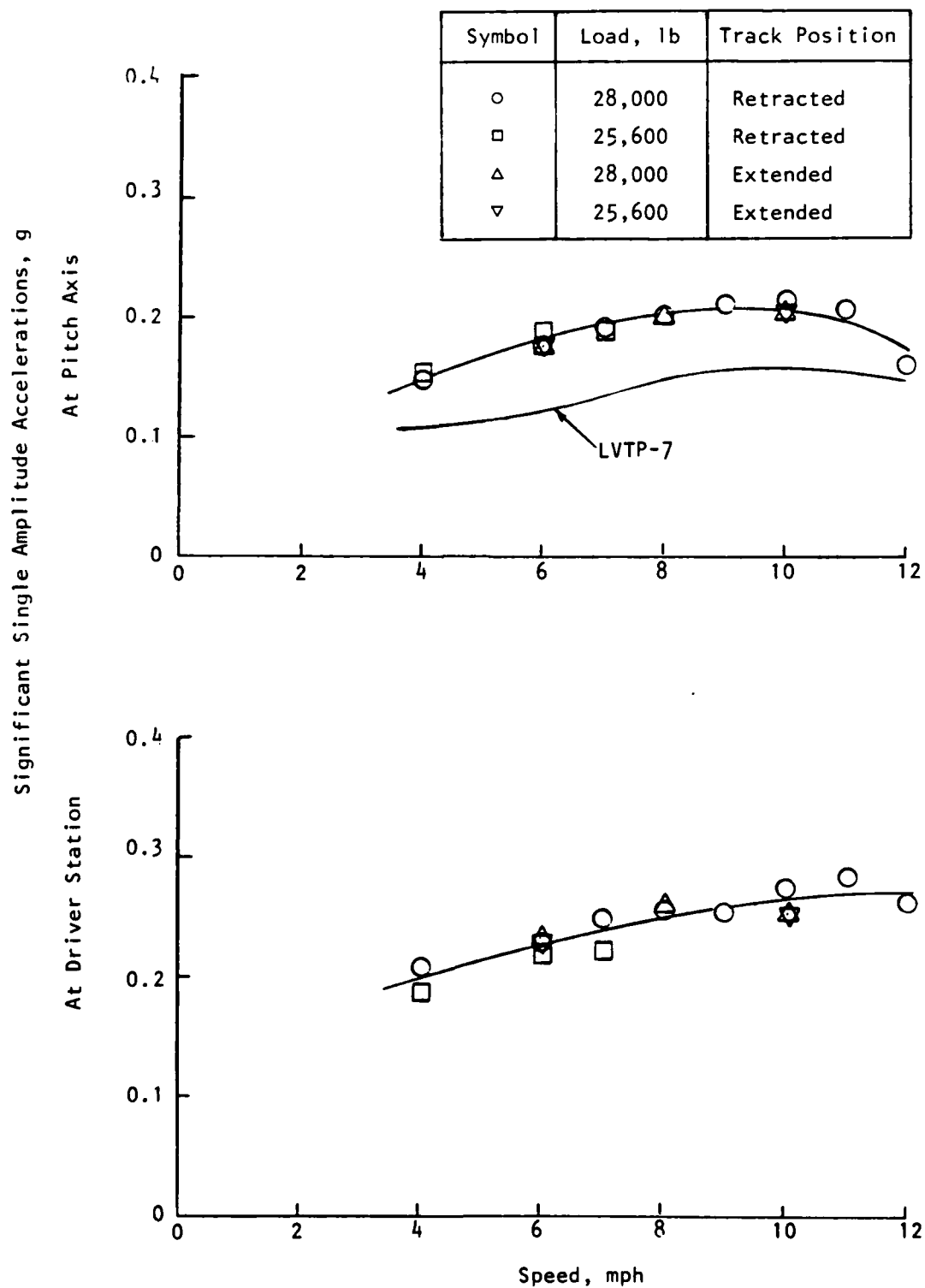


FIGURE 15 SIGNIFICANT ACCELERATIONS IN SEA STATE 2
BOW FLAP WITH DEADRISE AND GAP, WHEEL COVERS ON

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